

**Study of Earthquake Source and Crustal Structure in
the New Madrid Seismic Zone Region**

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Investigations Undertaken:

The significance of thin but extremely slow and inhomogeneous sedimentary basin to the determination of crustal velocity structure and hypocenter locations has been investigated in this study. 3-dimensional P- and S-wave velocity structures of the sedimentary basin in the upper Mississippi embayment have been constructed using priori information from (1) well logs, (2) geological formation and layer boundaries, (3) very shallow P and S wave velocities, and (4) arrival time differences between the direct S and the converted Sp waves from the bottom of the sedimentary basin. 3-dimensional Vp and Vs velocity information of the sediments determined in this study along with a PANDA velocity model are then input to provide important constraints in the initial model for a comprehensive 3-D velocity inversion. Earthquakes in the central NMSZ are relocated using the newly determined 3-D upper crustal Vp and Vs velocity structures. The active faults in the NMSZ are better imaged from the relocated earthquake hypocenters.

Results:

The sedimentary basin in the upper Mississippi embayment can be subdivided into eight layers of various thickness from the correlations between lithological formation and well-log information. Assuming a constant Vp/Vs ratio inside each individual layer of the same geological formation, Vp/Vs ratio for each layer beneath 35 PANDA stations can be determined from a linear inversion. The resultant Vp/Vs varies from 6.6 in the uppermost layer to 1.8 in the lowermost layer (Table 1). In general, Vp vary vertically from ~ 1.0 km/sec for the top layer to ~2.6 km/sec at the bottom layer beneath which Vp increases to 5.9~6.0 km/sec. The 3rd and 7th layers appear to be regions of lower Vp. Lateral variations of Vp inside layers are mostly in the range of 0.2~0.4 km/sec. The Vs increases from ~0.15 km/sec at

the uppermost layer to 1.37 km/sec at the deepest sedimentary layer. Lateral Vs variations inside each layer are similar to that of the Vp. Three-dimensional Vp and Vs structures in the upper Mississippi embayment can thus be constructed (Figure 1). The complexity of the vertically and horizontally varied seismic wave velocities inside the sedimentary basin can not be overlooked in traditional earthquake location and ground motion simulation for the region.

Crustal Vp and Vs structures are the two most essential components for a reliable earthquake location in the New Madrid Seismic Zone (NMSZ). The significance of the thin but extremely slow and inhomogeneous sedimentary basin to the determination of crustal velocity structure and hypocentral locations has been investigated in this study. 3-dimensional Vp and Vs velocity information of the sediments determined in this study and the previously determined 1-D PANDA model are input as a priori information in the initial model to determine upper crustal Vp and Vs velocity structures in the central NMSZ. The inversion method of Benz et al. (1996) modified by Shen (1999) has been applied to a group of selected earthquake data from PANDA experiment in the central NMSZ. After 14 iterations, a reduction of 52.9% and 74.2% of root mean square (RMS) travel time residual has been achieved from an initial value of 0.075 sec and 0.132 sec for P- and S-waves, respectively. Very significant lateral variation of Vp and Vs are found from many horizontally thin-sliced views of absolute velocities (Figure 2). Earthquake hypocenters can mostly be associated with regions of lower velocity or transition regions between low and high velocities. The relocated hypocenters using the new 3-D Vp and Vs information are deeper in the northern study area than the initial PANDA locations (Figure 3) which can be explained as the consequence of slightly over-estimated thickness of the sedimentary basin. On the other hand, the relocated hypocenters are shallower in the southern study area than the initial PANDA locations which can be interpreted as the results of a under-estimated thickness of sediments in the original PANDA locations (Figure 3). The relocated hypocenters allow a reliable image of the vertically dipping SW, NW, and NE segments and the gently dipping Central segment of the NMSZ, which are similar to those of Chiu et al. (1992), but with better constraints on focal depths. Furthermore, the relocated hypocenters in this study are also consistent with those relocated by using the JHD technique (Pujol et al., 1997).

Non-technical Summary :

Because of its relative thin thickness (≤ 1000 m), structure of the sedimentary basin in the upper Mississippi embayment has

long been overlooked until recently in earthquake location and earthquake hazard assessment for the central U.S. We investigate the 3-dimensional velocity structure of the basin using recently available well-logs, shallow seismic profiles, lithological information, and high-quality PANDA data. A well-determined structure for the sedimentary basin will improve significantly the resolution power of 3-dimensional tomographic inversion of the upper crustal structure in the upper Mississippi embayment which is critical for a reliable earthquake location and strong ground motion simulation for the region.

Reports Published :

Two abstracts from two papers in their final stage of preparation were presented in the 71th annual meeting of the Eastern Section Seismological Society of America held October 1999 in Memphis. They are :

3-D P- and S-wave velocity structures in the sedimentary basin of the upper Mississippi embayment, *Seismol. Res. Lett.*, Jan.2000, F. Gao, J.M. Chiu, E. Schweig, and R. Street.

Three-dimensional upper crustal Vp and Vs structures in the central New Madrid seismic zone, *Seismol. Res. Lett.*, Jan. 2000, F. Gao, J.M. Chiu, E. Schweig, J. Pujol, and R. Street.

Data Available :

The digitized well log data, Vp and Vs profiles beneath 35 PANDA stations, Travel time differences between the direct S and the converted Sp arrivals at 35 PANDA stations, 3-D upper crustal Vp and Vs information, and PANDA earthquake data (about 2 GB in PANDA or SEED format) will be available upon request. Please contact Jer-Ming Chiu at 901-6784839 or chiu@ceri.memphis.edu for information.

Table 1. Initial and Final Values of Vp, Vs, and Vp/Vs for the Sedimentary Layers beneath a PANDA Station (36.361° N, 89.542° W)

Layer	1	2	3	4	5	6	7	8
Vp(m/s)	957.8	1940.0	1745.9	1990.9	2015.1	2038.3	1960.9	2277.9
Vs(ini)	145.1	248.7	301.0	497.7	671.7	689.4	784.4	911.0
Vp/Vs(ini)	6.6	7.8	5.8	4.0	3.0	3.0	2.5	2.5
Vp/Vs(fin)	6.6	7.8	5.2	3.1	2.7	2.5	1.7	1.8
$\Delta(Vp/Vs)$			0.05~ 0.16	-0.02~ 0.10	-0.06~ 0.02	0.16~ 0.28	-0.01~ 0.10	-0.07 0.07

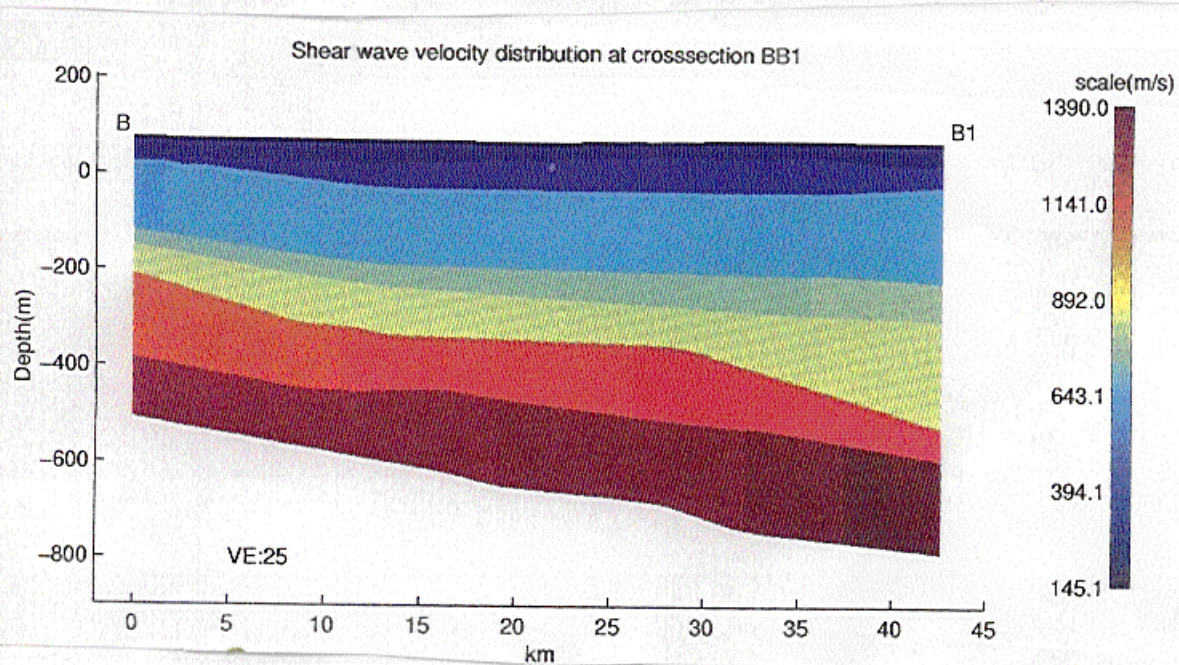
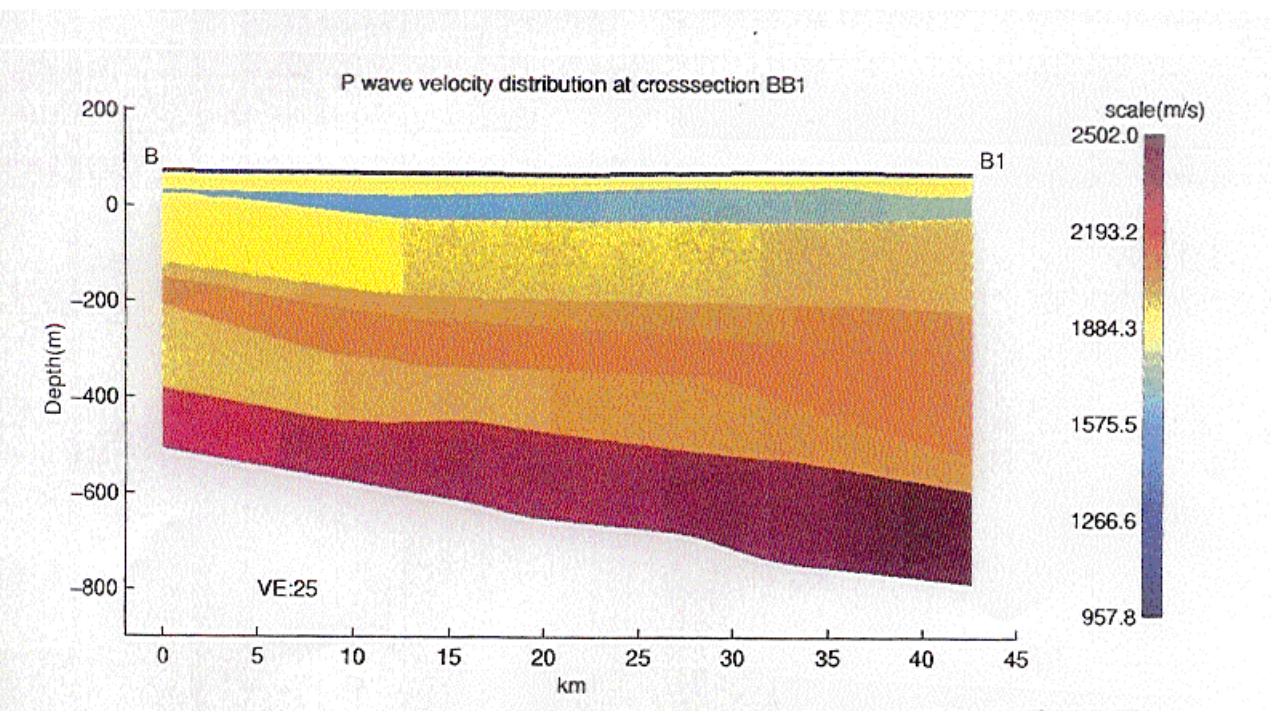


Figure 1. East-west cross sectional views of V_p (top) and V_s (bottom) profiles for the Sedimentary basin in the upper Mississippi embayment showing vertical and horizontal variations of seismic velocities.

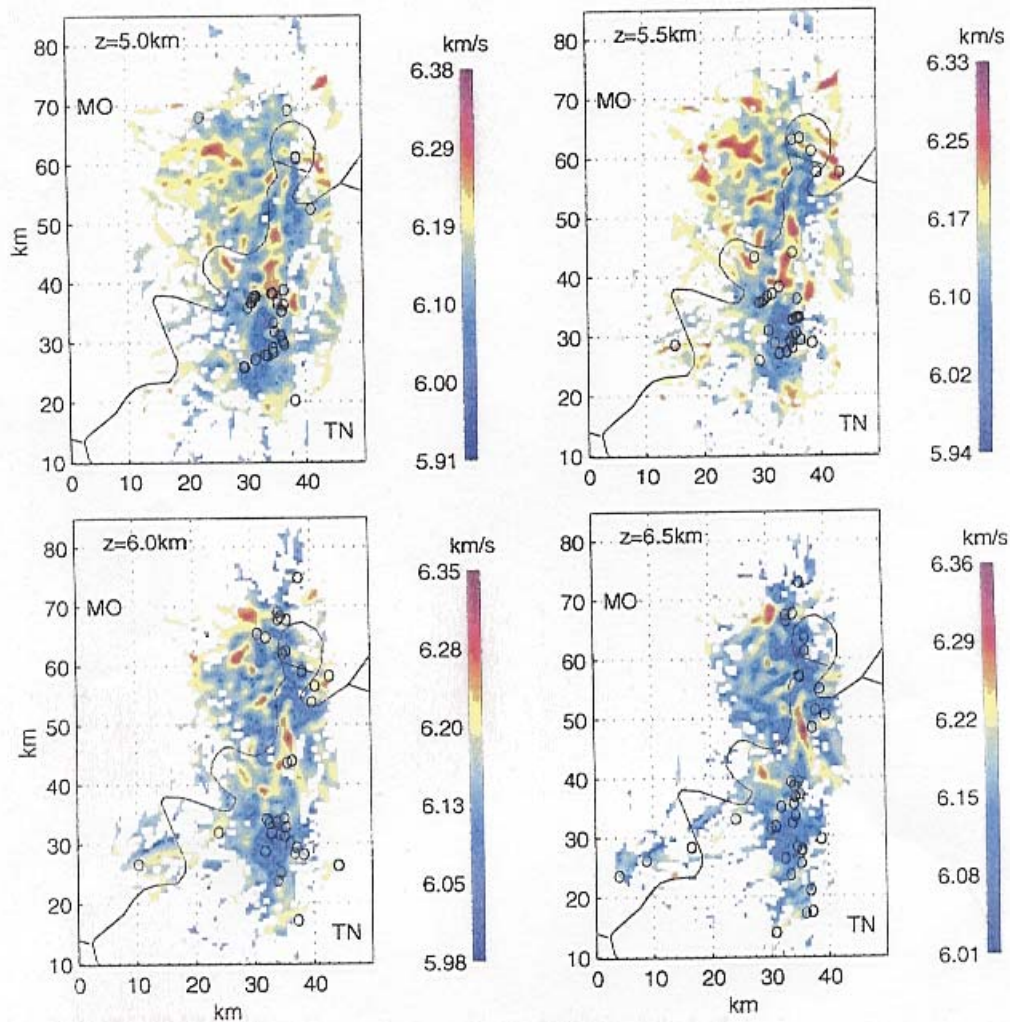


Figure 2. Examples of horizontally thin-sliced V_p sections at depths of 5, 5.5, 6, and 6.5 km in the New Madrid seismic zone from 3-D tomographic inversion analysis of PANDA data. 3-dimensional V_p and V_s velocity structures for the shallow sedimentary basin and 1-D velocity model from PANDA study were input to construct a reliable initial model for the inversion. Absolute P-wave velocities are shown.

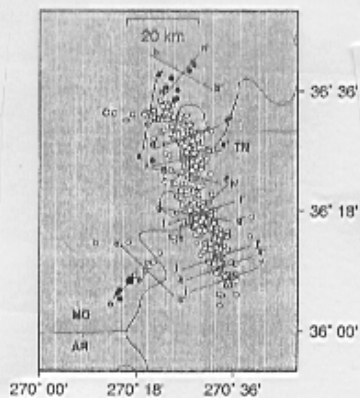
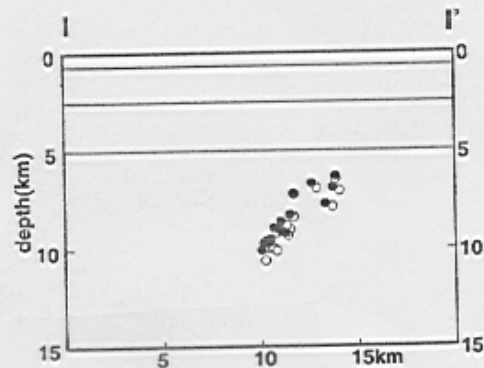
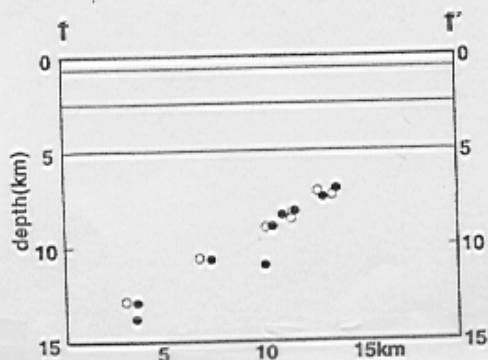
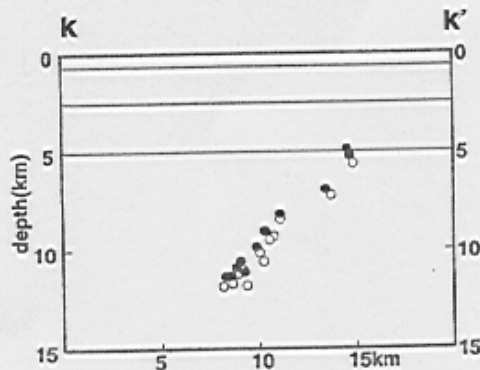
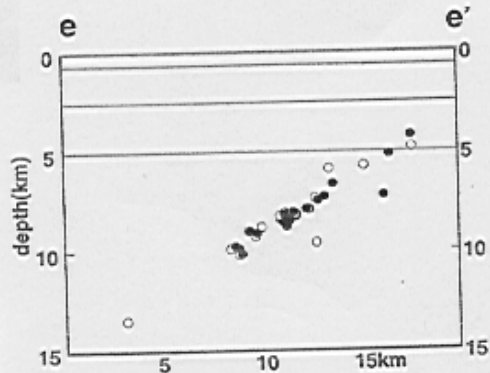
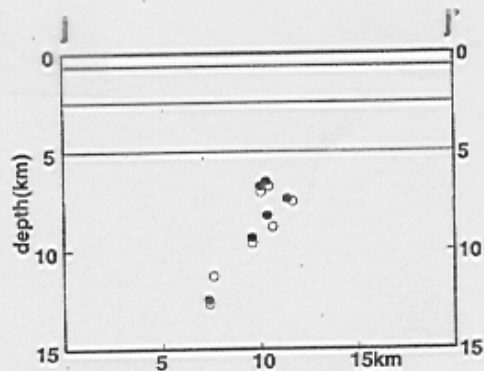
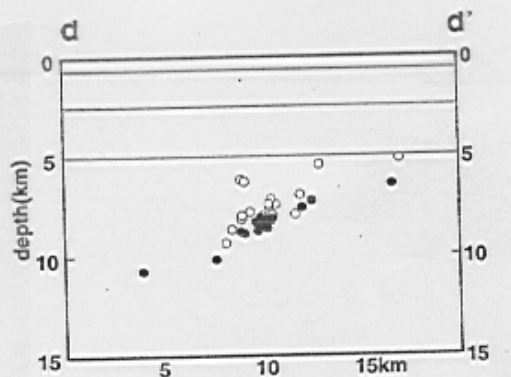


Figure 3. Cross-sectional views of hypocenters along the northern (dd', ee', and ff') and the southern (jj', kk', and ll') portions of the central New Madrid seismic zone (CNMSZ) showing the original (open circle) and the relocated (solid circle) hypocenters. It is clear that the relocated hypocenters are in general deeper and shallower, respectively, in the northern and southern CNMSZ than the original PANDA locations.